

Microfabrication Technologies for Target Fabrication



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Atomic layer deposition (ALD) is the newest form of chemical vapor deposition technique capable of achieving atomic monolayer layer thickness while conformally coating in deep complex structures. This technique has been used to make novel structures such as nano-film capacitors, nano-FETS and tunable nano-magnetic structures. LLNL has purchased an ALD tool primarily for coating foams for physics targets.

Project Goals

This project was used to become familiar with the operation of the ALD tool, to make the appropriate fixtures to use the tool on a number of substrates of interest, and to characterize the tool for use with various deposited layers.

Relevance to LLNL Mission

Many materials in target fabrication, in particular the low-density foams used for current capsules, can be fabricated using an ALD system. ALD works by using a two-step deposition process. First, a vapor-phase precursor is introduced which reacts only with the substrate surface. Because only an exposed surface can be coated in this step, a monolayer is applied to the substrate and over a period of time the gas penetrates into the crevices of the structure applying this monolayer uniformly over complex structures. A second vapor-phase precursor is introduced that reacts only with the deposited layer of the first precursor to create a new layer of the desired substrate material, which is now able to react again with the first precursor gas. The precursor gases are alternately introduced into the reaction

chamber and with each cycle an additional atomic layer is deposited. The high vapor pressure of the gases allows for the penetration into high-aspect-ratio features. The number of cycles determines the deposition thickness.

Many of the targets used in physics experiments require low densities of specific materials. One mechanism for producing these materials is to coat foam material with the material of interest. Foam structures such as silica aerogel are complex porous materials. The ALD precursor gases can penetrate into the lattice of the foams and apply an ultrathin layer to the foam ligaments. In this way, it is possible to create any number of low-density metal foams such as copper, tungsten, or platinum foams.

FY2009 Accomplishments and Results

The ALD system was installed in LLNL's Microfabrication Facility clean-room. Results indicated good uniformity of the alumina depositions across a planar wafer (< 0.1% variation across a 100-mm wafer). The ALD system was also characterized for its ability to coat high-aspect-ratio features using the dynamic process mode. A covered (100) silicon wafer with anisotropic etched V-grooves was used for the experiment. The groove depths ranged from 5 to 178 μm . A standard coating process for aluminum oxide (Al_2O_3) was run at 200 °C using trimethyl aluminum (TMA) and water vapor at 1 Torr. The process is a sequential cycle involving the introduction of the precursor TMA followed by a purge evacuation. The second precursor

water vapor was introduced, followed by a purge evacuation. The precursor injection times and purge times were adjusted so that 1 Å of film was deposited in one complete cycle. The precursors must be entirely removed before the second precursor is injected, otherwise an uncontrolled chemical vapor deposition process results and the process is no longer an atomic layer deposition process.

One thousand cycles resulted in a film thickness of 1018 Å. The film thickness was measured with a Rudolph Research AutoEl-III ellipsometer at a wavelength of 632.8 nm using Program Code 211000 and refractive index of Al_2O_3 of 1.766. The Al_2O_3 coating penetration into the covered silicon V-grooves was measured using an optical microscope. A graph of the coating penetration depth versus the V-groove depth (Fig. 1) shows a coating penetration with increasing V-groove depth. The coating penetration reached a maximum of 6 mm due to the diffusion rate limitations of the precursors in the dynamic ALD mode. In order to increase the coating penetration into trench structures and foams, the static mode ALD process can be used.

A lift-off process to pattern ALD coatings was successfully created. Positive photoresist was patterned on a silicon wafer and hard baked at 120 °C. The wafer was then coated with 500 Å of Al_2O_3 using an ALD process operating at a temperature of 90 °C and chamber pressure of 1 Torr. This lower deposition temperature was selected to prevent the photoresist from outgassing or decomposing during the deposition. The photoresist was then removed by submerging the wafer in acetone in an ultrasonic bath. The ALD coating on the photoresist was successfully removed, resulting in the patterned Al_2O_3 structure shown in Fig. 2. The photoresist was not damaged during the ALD process. The 90 °C process was sufficiently low temperature to prevent flowing or decomposition of

the photoresist. The rough edge artifacts on the Al_2O_3 structure are a result of the ALD coating the sidewalls of the photoresist. The rough edges can be minimized by reducing the coating thickness, thereby providing a cleaner separation of ALD film on the photoresist sidewall. The process will have applications in selective patterning of materials for sensors and catalyst.

Related References

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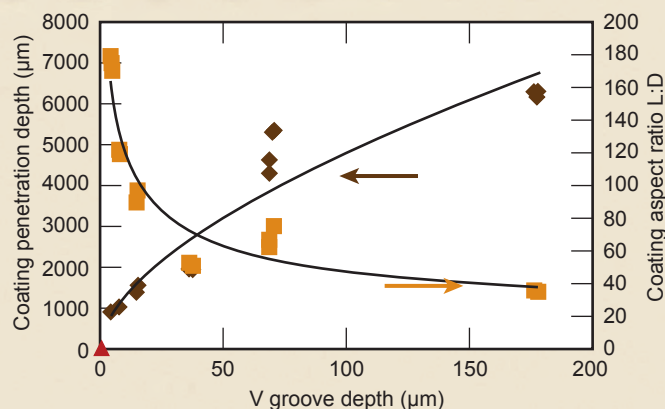


Figure 1. ALD coating penetration into silicon V groove channel.

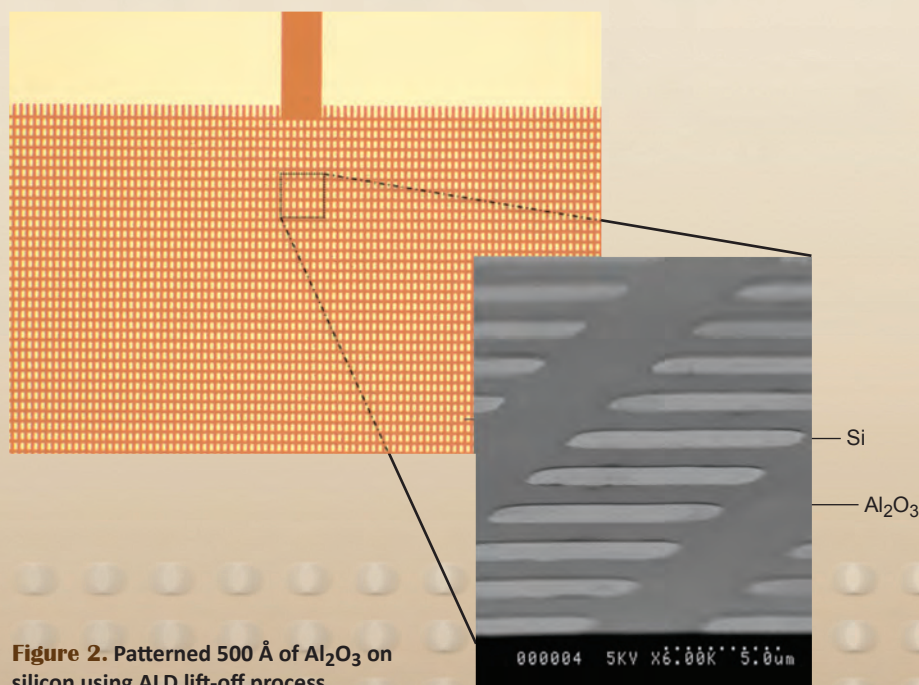


Figure 2. Patterned 500 Å of Al_2O_3 on silicon using ALD lift-off process.